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Effect of Drip Fertigation on Growth, Yield Parameters and Fertilizer use Efficiency of Irrigated Cotton (*Gossypium hirsutum* L.) under High Density Planting System

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A B S T R A C T

A field experiment was conducted at Department of Cotton, Tamil Nadu Agricultural University, Coimbatore during winter irrigated season 2019-2020 to study the effect of drip fertigation on growth and yield parameters and fertilizer use efficiency (FUE) of cotton under high density planting system (HDPS). The field study consisted of eight treatments, in which drip fertigation was given in T_1 to T_3 with 75%, 100% and 125%of recommended dose (RDF, 80:40:40 kg NPK/ ha) as straight fertilizers N and K (urea and MOP) and SSP was applied as basal dose. In T_4 to T_6 fertigation provided with 75%, 100% and 125% RDF of water soluble fertilizer (19:19:19). Drip irrigation with 100% RDF (all as soil application) was given in T_7 and T_8 with drip irrigation and STCR based fertilizer application. The experiment was replicated thrice in Randomized Block Design. The treatment T_6 where drip fertigation supplied with 125% RDF of WSF recorded the highest growth parameters (plant height, leaf area index and dry matter production) and yield parameters (number of sympodial branches/plant, number of bolls/plant, boll weight and seed cotton yield) compared to all other treatments. 75% RDF through WSF recorded highest nitrogen FUE and drip irrigation with STCR based fertilizer application reported highest values of phosphorus and potassium FUE.

Introduction

Cotton, the widely known 'white gold' is the most important fibre cum cash crop in the world next to food grains that play a vital role in Indian national economy (Patel *et al.*, 2016), which accounts for 25% of the total global fibre production and being the backbone of Indian textile industry, 59% of the fibre is consumed as raw material for textiles. India is the leading country with largest area (12.58 million ha) and production (36.0million bales) of cotton with the yield of 486.33 kg ha^{-1} (Indiastat, 2019).

Major cotton growing countries like USA, Australia, China, Brazil and Uzbekistan are adopting a high density planting system with wider row to row spacing ranging from 30-100cm and 8-10cm spacing between plants to

obtain higher yields by maintaining straight varieties (Gaikwad *et al.*, 2018). Accommodating a huge number of plants per unit area have been considered as an alternate production system with a potential for improving the productivity, profitability and input use efficiency and reducing input costs and minimizing the risks associated with the current cotton production system in India (Venougopalan *et al.*, 2014).

Excess amount of fertilizers are being dumped in fields by farmers to get more yield which is one of the major reasons for environment pollution. Also nearly half of the irrigation water applied through different unscientific methods is being wasted. Drip fertigation is the most appropriate solution to save our inputs like water and nutrients and is the most effective form of utilization.

Application of fertilizers in dissolved form along with irrigation water through a drip system is a promising modern agro technique which provides an excellent opportunity to maximize yield and minimize environmental pollution (Hagin *et al.*, 2002). By providing the readily available form of the nutrients directly to the crop root zone, it has become the most efficient and agronomically sound method which can minimize fertilizer application rate and increase the fertilizer use efficiency, so that a good proportion of total fertilizers to be applied can be saved.

In this context, the present field study is formulated to investigate the effect of drip fertigation in high density planted cotton during winter irrigated season in order to sustain cotton productivity, economic and environment safety as well. Here, the effect of normal straight fertilizers (N and K) are being compared with that of water soluble fertilizer on various growth, yield parameters and FUE of cotton under drip fertigation.

Materials and Methods

Field experiment was carried out during winter irrigated season of 2019-2020 at the Department of Cotton, Tamil Nadu Agricultural University, Coimbatore located at western agro-climatic zone of Tamil Nadu at latitude of 11.23˚N, longitude of 77.10˚E and at an altitude of 428.5 meters above mean sea level. The soil of experiment site was well drained, sandy clay loam in texture and slightly alkaline in reaction (8.5). Initial soil samples were collected and analyzed for available N, P and K nutrients.

The results showed that the soil was low in nitrogen (193.2 kg ha^{-1}), high in both phosphorus (35 kg ha^{-1}) and potassium(686 kg ha^{-1}). The total rainfall received during the cropping season was 721 mm. TCH 1819, which is recently released by TNAU as CO 17 was selected and seeds were dibbled at a depth of 3-5cm on 30thjuly 2019 at a spacing of 75 x 15 cm by ensuring a population of 88,888 plants ha^{-1}.

The experiment was laid out with eight treatments replicated thrice in Randomized Block Design (RBD). The experiment comprised of T_1- Drip fertigation (DF) with 75% recommended dose (RDF) (60:30:30 kg ha^{-1}) of straight fertilizers N&K (Urea & MOP), T_2- DF with 100% RDF (80:40:40 $kgha^{-1}$) of straight fertilizers N&K, T_3- DF with 125% RDF(100:50:50 $kgha^{-1}$) of straight fertilizers N&K, T_4- Drip fertigation with 75% RDF as water soluble fertilizers(WSF)-19:19:19, T_5- Drip fertigation with 100% RDF of WSF, T_6- Drip fertigation with 125% RDF of WSF, T_7- Drip irrigation with soil application of 100% RDF (80:40:40 $kgha^{-1}$) and T_8- Drip irrigation with soil application of STCR based fertilizer application. Phosphorus was applied as basal dose in the form of single super phosphate (SSP) in the treatments T_1, T_2 and T_3.

Drip irrigation system with emitter-emitter spacing of 0.4m were laid in the field according to the treatments. Fertigation was given through the drip lines with the help of ventury assembly for easy delivery through emitters. Straight fertilizers (urea and MOP) and water soluble fertilizer (19:19:19) were used as nutrient sources for fertigation. Treatments T_4, T_5 and T_6 were supplied with extra urea through fertigation to meet the remaining nitrogen needs of the crop. Fertigation was given once in a week from 15^{th} day to flowering and boll development stage and irrigation was scheduled based on the prevailing weather parameters.

The growth parameters were recorded from five tagged plants treatment wise from each plot in every thirty days interval. The recommended package of practices was followed during the course of the experiment. The collected data was statistically analyzed under randomized block design as suggested by Gomez and Gomez (2010).

Results and Discussion

Plant height (cm)

Plant height was significantly influenced by fertigation treatments. The highest plant height was recorded in T_6 and the least value in T_8, since the fertilizer applied is too low (STCR based). As the fertilizer level increased from 75% RDF to 125% RDF in drip fertigation the plant height also increased linearly. This finding was in confirmation with Kakade *et al.,* (2017) who concluded that there was a gradual increase in plant height with each increasing level of recommended dose of N and K from 50 to 125 per cent in drip fertigation. Bibi *et al.,* (2011) and Udikeri and Shashidhara (2017) also reported that plant height increased linearly witheach increment of N from 0 to 150 kg/ha.

The plant height recorded in treatments T_4 to T_6 showed superior values than that of T_1 to T_3 which clarified that water soluble fertilizer (WSF) was more efficiently utilized by the cotton crop than the normal straight fertilizers in fertigation technique. Similar findings were given by Rajendran and Arunvenkatesh (2014) who has concluded that drip fertigation with 150 per cent recommended dose of NPK as WSF registered significantly highest plant height of 123.3 cm at 105 DAS than other treatments.

Kavitha *et al*., (2007) in tomato crop and Fanish and Muthukrishnan (2011) in maize crop have reported that the increased plant height with 100 per cent RDF through water soluble fertilizers might be due to the presence of favourable microclimate to the plants and application of sufficient nutrients in a readily available form that would have accelerated the production of growth regulators such as auxins (IAA) and cytokinins which in turn stimulated the action of cell elongation and cell division and resulted in increased plant height.

Leaf Area Index

There was an increasing trend in the values of LAI from T_1 to T_3 and T_4 to T_6 since the recommended dose of fertilizers increased. In every growth stages of the crop, highest LAI was recorded in treatment T_6 with 125% of WSF in drip fertigation and the lowest value was recorded in treatment T_8 where fertilizer was applied on STCR basis through drip irrigation. Increased level of fertilizer dose in the form of WSF might have increased the availability of required nutrients to the crop root zone which obviously led to higher uptake and assimilation of nutrients.

Drip fertigation of N and K fertilizers with higher levels of 125 per cent RDNK ha^{-1} registered their superiority in enhancing all

the growth attributes over lower fertigation levels (50, 75 and 100 per cent) and over conventional method of soil application with 100 per cent RDF of NPK (Kakade *et al.*, 2017). Ghule *et al*., (2013) also noted similar trend in cotton. Increased level of RDF might have resulted in more number of functional leaves per plant along with the dimensions of a leaf finally led to a higher value of LAI.

Dry matter production (g/plant)

The total dry matter produced per plant showed significant difference among the treatments and it was higher in treatment T_6 with 125% of RDF in drip fertigated system than all other treatments. As the fertilizer dose increased, the dry matter production also increased in each stages of cotton under drip fertigation and the trend of fertigated treatments was superior to T_7 and T_8 where drip irrigation with soil application of fertilizer was followed. Increased availability of nutrients might have enhanced the growth parameters especially plant height, number and size of the leaves there by the drymatter production in each stages of the crop growth. The increase in dry matter due to increased level of fertilizers was also reported by Ram and Giri (2006), Ghule *et al*., (2013) and Udikeri and Shashidhara (2017).

Veeraputhiran (2000) and Bhalerao *et al.*, (2011) reported that fertilizers when applied through fertigation in splits recorded higher dry matter accumulation in cotton. Nalayani *et al.*, (2012) and Gokila (2012) also reported that split application of N and K in more split enhanced the dry matter production. Sagheb *et al.*, (2002) tried different methods of application of same quantity of fertilizers and found that about 2.7 times more total dry matter was produced in drip fertigation in comparison with treatment with furrow irrigation and soil application of fertilizers.

In maize crop, maximum dry matter per plant was recorded in 100 % RDF through drip than rest of the fertigation levels including 75% RDF through drip, 100% RDF through soil and 50% RDF through drip. So it was concluded that maize crop showed better response to increased fertilization of NPK and also better performance of water soluble fertilizers over application of fertilizers through soil (Bibe *et al.*, 2018). These results were in confirmation with Sampatkumar and Pandian (2010) and Muthukrishnan *et al.*, (2011).

Number of sympodial branches/plant

Significant difference existed in number of sympodial branches produced in cotton (Table 2). As the applied dose of fertilizers increased the numbers of sympodial branches produced were also increased. Treatment T_6 followed by T_5 and T_3 recorded higher value of fruiting branches per plant and the least number of sympodial branches were recorded in T_7 where drip irrigation with 100% of RDF was applied in soil.

Increased number of sympodial branches in drip fertigated treatments might be due to the enhanced availability and uptake of nutrients which might have resulted in further vegetative growth of the cotton (Kakade *et al.*, 2017). Application of higher level of N and K through fertigation and its enhanced effect on number of sympodial branches produced per plant were reported by Veeraputhiran (2000), Bhalerao *et al.*, (2011) and Gokila (2012).Bibi, *et al.*, (2011) reported that the fruiting branches were significantly increased with increase in N levels from 0 to 150 with values from 10.33 to 19.33 when averaged across cultivars. Karthikeyan and Jayakumar (2002) observed similar trend which eventually increased seed cotton yield as compared to control.

Number of bolls

Number of bolls per plant was significantly affected by drip fertigation treatments. Drip fertigation with 125% RDF of WSF (T_6) recorded highest number of bolls per plant followed by 100% RDF of WSF(T_5), 125% RDF of straight fertilizers N and K(T_3) which was on par with drip irrigation with STCR based fertilizer application(T_8) in both 90 and 120 DAS.

The increased number of fruiting branches in accordance with increased dose of N and K through WSF in fertigation, have increased the no of bolls as well.

Brar *et al.,* (1993) revealed that increased nitrogen doses increased plant height and number of bolls. Similar results were reported by Gokila (2012) and Khan *et al.,* (2001) who revealed that nitrogen levels significantly affected sympodial branches, bolls per plant and seed cotton yield, and nitrogen @ 187 kg ha^{-1} provided significant increase in yield components and yield.

Boll weight

Like the number of sympodial branches and no. of bolls produced per plant, boll weight was also significantly influenced by drip fertigation in which 125% RDF of WSF marked the highest boll weight (5.6g) followed by 100% RDF of WSF (4.78g), 125% RDF of straight fertilizer (4.62g) which was on par with drip irrigation with STCR based fertilizer application (4.60g).

Increased level of fertilizer doses through drip fertigation might have increased the photosynthetic rate and accumulation of metabolites by the plants which resulted in higher boll weight. Also WSF enhanced the easy access of required nutrients to plants so that recorded a great impact on boll weight than that of straight fertilizers.

Table.1 Effect of drip fertigation on growth parameters

Treatment	Plant height (cm)				Leaf Area Index				Dry matter production (g/plant)			
	30 DAS	60 DAS	90 DAS	120 DAS	30 DAS	60 DAS	90 DAS	120 DAS	30 DAS	60 DAS	90 DAS	120 DAS
T1	23.00	44.8	72.00	87.74	0.50	1.78	3.00	2.58	2.41	9.80	42.26	82.33
T2	29.87	50.48	84.05	95.05	0.69	1.89	3.78	3.08	3.00	10.13	52.00	92.30
T3	31.50	56.49	88.80	104.98	0.80	2.55	4.66	3.45	4.12	12.75	61.50	116.00
T4	27.02	45.83	83.45	94.13	0.54	1.68	3.46	3.16	2.67	10.98	48.00	89.15
T5	28.15	57.94	89.30	98.00	0.59	1.82	4.16	3.42	3.90	12.94	54.33	109.54
T6	32.45	60.00	95.60	124.30	0.81	2.83	5.07	3.59	4.72	14.41	69.80	128.50
T7	31.75	52.00	71.50	94.32	0.75	1.80	3.50	3.17	3.56	11.94	58.00	90.00
T8	22.67	43.00	66.00	82.51	0.46	1.12	2.67	2.17	2.24	9.00	39.33	80.98
SEd	**2.32**	**4.10**	**6.57**	**7.83**	**0.05**	**0.15**	**0.29**	**0.24**	**0.25**	**0.88**	**4.18**	**7.69**
CD	**4.98**	**8.79**	**14.09**	**16.79**	**0.11**	**0.32**	**0.63**	**0.52**	**0.54**	**1.89**	**8.97**	**16.49**

Table.2 Effect of drip fertigation on yield parameters

Treatment	Number of sympodial branches/ plant				No. of bolls/ plant		Boll weight (g)	Seed cotton yield (kg/ha)
	30 DAS	60 DAS	90 DAS	120 DAS	90 DAS	120 DAS		
T1	0.07	4.87	8.48	10.15	7.5	8.5	4.00	2721
T2	0.20	5.00	9.73	12.33	8.70	9	4.17	3252
T3	0.27	5.07	11.20	13.40	9.79	11	4.60	3765
T4	0.20	4.90	10.05	10.87	7.80	9.6	4.36	3423
T5	0.40	5.53	11.90	13.56	9.73	10.85	4.58	3795
T6	0.63	7.53	12.54	14.20	11.00	12.24	5.20	4073
T7	0.31	4.93	9.50	10.30	8.20	10.25	4.23	3056
T8	0.33	5.27	10.97	11.60	10.38	12.00	4.65	3691
SEd	**0.02**	**0.44**	**0.86**	**0.99**	**0.77**	**0.87**	**0.37**	**286.86**
CD	**0.05**	**0.93**	**1.85**	**2.13**	**1.65**	**1.88**	**0.79**	**619.34**

Table.3 Effect of drip fertigation on Fertilizer Use Efficiency

Treatment	Fertilizer Use Efficiency (kg $kg^{-1)}$		
	Nitrogen	Phosphorus	Potassium
T1	45.83	90.68	92.65
T2	40.75	82.15	82.15
T3	37.76	75.54	75.54
T4	57.04	114.07	116.56
T5	47.55	94.36	94.36
T6	40.89	81.79	81.81
T7	38.30	76.48	76.60
T8	51.58	185.47	188.26
SEd	**3.91**	**10.34**	**10.47**
CD	**8.39**	**22.18**	**22.46**

Bibi *et al.*, (2011) noted that increase in N levels from 0 to 150 kg ha^{-1} have significantly increased boll weight. Similar results were reported by Khan *et al.*, (1993) who found that boll weight increased as N rate increased from 95 to 143 kg ha^{-1}.Bhalerao *et al.*, (2011) and Gokila (2012) reported that total bolls produced per plant and individual boll weight were significantly higher in cotton applied with higher level of nutrients through fertigation and the similar observation was noted by (Jayakumar *et al.*, 2015) in fertigation through WSF.

Yield

Existence of significant influence in drip fertigation on seed cotton yield was enhanced due to the positive role of major yield contributing characters such as number of sympodial branches, bolls per plant and boll weight. Maximum yield was recorded in drip fertigation with 125% RDF through WSF(4073 kg ha^{-1}), followed by 100% RDF through WSF (3795kg ha^{-1}) which was on par with 125% RDF of straight fertilizer (3765 kg ha^{-1}), followed by drip irrigation with STCR

based fertilizer application (3691 kg ha^{-1}). Minimum yield was recorded by drip fertigation with 75% RDF of straight fertilizer (2721 kg ha^{-1}).

The increased level of fertilizer from 75 to 125% RDF might have increased the vegetative growth, photosynthetic rate, accumulation and translocation of metabolites from source to sink which directly expressed in the form of increased seed cotton yield. Similar result was given by Prince *et al*., (1988) in bell pepper. In drip fertigation, seed cotton yield increased linearly with increased doses of fertilizer. Nalayani *et al.*, (2012) and Kakade *et al.,* (2017) have reported similar findings that fertigation with 125% recommended dose of N and K increased yield attributes than other lower levels and soil application of fertilizers.

The superior effect of WSF on seed cotton yield might be due to higher percentage of nutrients derived from fertilizer applied and efficient nutrient uptake by cotton plants. Similar response of increased yield through drip fertigation with WSF was reported by Bhakare *et al.,* (2015) in cotton and Fanish and Muthukrishnan (2011) in maize.

Fertilizer Use Efficiency (FUE)

Drip fertigation treatments had a remarkable impact on FUE. It showed a decreasing trend towards increasing fertilizer doses. Highest nitrogen fertilizer use efficiency was recorded in T_4 (57.04 kg/ kg nitrogen) with 75% RDF of WSF and it was followed by drip irrigation with application of STCR based recommendation of fertilizer (51.58 kg/ kg nitrogen). The least FUE was recorded in T_3 (37.76kg/ kg nitrogen) in which 125% of straight fertilizers were used. Maximum phosphorus and potassium fern tilizer use efficiency was recorded in T_8 with drip irrigation and STCR based fertilizer application (185.47kg/ kg phosphorus and 188.26kg/ kg potassium respectively) followed by 75% RDF through WSF (114.07kg/ kg phosphorus and 116.56 kg/ kg potassium respectively).125% RDF through straight fertilizer noted the least values of 75.54 kg/ kg for phosphorus and potassium.

Even though yield increased with increase in fertilizer doses, the FUE decreased. Similar findings were reported by Singandhupe *et al*., (2005). The experiment revealed that water soluble fertilizers were utilized more efficiently by cotton plants than normal straight fertilizers in drip fertigation. Application of WSF through fertigation treatments might have distributed better through root zone of crop than straight fertilizers and soil applied treatments, thus producing more available amounts for plant uptake to improve FUE.

Bhakare and Fatkal (2008) observed highest FUE when 50 per cent RDF was applied through drip irrigation. They found lowest FUE when 100 per cent RDF was applied through conventional fertilizer application method and irrigation water was applied by surface application.

From the present field study it could be concluded that growth and yield parameters and FUE were highly influenced by drip fertigation in cotton under HDPS. Application of 125% RDF through WSF registered a remarkable increase on growth and yield parameters than all other treatments, based on which T_6 can be considered as the best treatment. Seed cotton yield obtained from 125% RDF of straight fertilizer was similar to that of 100% RDF of WSF which showed that almost 25% of fertilizer use can be saved by using WSF instead of straight fertilizer through drip fertigation without any reduction in yield. Drip irrigation with soil test based fertilizer application with 73kg N, 20kg P_2O_5

and 20kg K_2O ha^{-1}(T_8) also could reach comparable yield with that of T_5 (100% RDF through WSF) and T_3 (125% RDF through straight fertilizer) through which cost on nutrients can be saved. FUE was decreasing with increase in fertilizer doses. Nitrogen FUE was found to be higher in T_4(75% RDF of WSF) but phosphorus and potassium FUE were higher under T_8(drip irrigation with STCR based fertilizer application). Fertilizer nutrients were more efficiently utilized with minimum wastage by drip fertigation technique compared to conventional method of irrigation and fertilization.

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